First Results from a Hydrostatic Levelling System Installed at Diamond Light Source

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Abstract

A Hydrostatic Levelling System (HLS) has been newly installed at Diamond Light Source. 8 sensors have been positioned along a 60 metre portion of the floor of the storage ring and the experimental hall, stretching out along a typical beamline route from Insertion Device to sample. The foundations and floor were designed to achieve settlements measuring 1 micron per 10 metres per hour and 10 microns per 10 metres per day but up until now it has not been possible to measure these very small movements. The design specification also called for the hall floor to be stiff enough that with an applied local load of 500kg, the deflection measured 2 metres away should only be 1 micron. The HLS should also be able to measure this aspect of performance as well as longer term seasonal variations. First results are presented.

1. Introduction

Diamond Light Source is a 3rd generation synchrotron light source built in the UK. It commenced operations in January 2007 and now has 11 beamlines in operation with a further 4 due to become operational later in 2008. As with all synchrotron light sources, floor and foundation stability is a key requirement for high brightness. There are typically 45 to 50 metres from the focal point of the electron beam, where the X-ray photons are produced, to the tiny photon focal spot at the beamline sample. Both positions are measured in microns. A floor stability specification was generated (Table 1) aimed at achieving the performance required but using economic construction practices. Other factors contributing to the specification included typical equipment weights as well as the effect of a visitor party walking close by a beamline experiment. The specification allowed the building design to proceed, utilising Finite Element Analysis to predict the performance of the floor slab but now the building is complete a HLS system purchased from Fogale Nanotech* has been installed as the most practical method to measure actual performance.

Table 1: Floor Specifications

Load Condition	***Target Performance***
5kN applied load	*6 micron deflection under the load and 1 micron 2 metres away*
Short term settlement	*1 micron over 10 metres per hour and 10 micron over 10m per day*
Long term settlement	*100 micron over 10 metres per year for the Storage Ring and 250 micron over 10 metres per year for the Experimental Hall*

2. Description of the Diamond building, floor and foundations

A cross-section of the Diamond building is shown at Figure 1. Diamond has a circular building of outer diameter 235m employing a steel frame with 96 equally spaced columns at the inner and outer circumference mounted on pad foundations. The Storage Ring (SR) tunnel is built on an 850mm thick reinforced concrete slab and the Experimental Hall (EH) slab is 600mm thick. These slabs are cast together with no open radial or circumferential joints between them and are cast onto a network of 600mm diameter piles, each 12-15m deep and arranged on a 3m grid. A 60mm void has been created under these slabs to allow the chalk soil to shrink and swell due to the varying water table without stressing the floor. The peripheral offices, laboratories and workshops as well as the inner plant spaces are built on surface cast slabs which are separated from the piled slab by sealed construction joints approximately 30mm wide.

* http://www.fogale.fr/pages/index.php

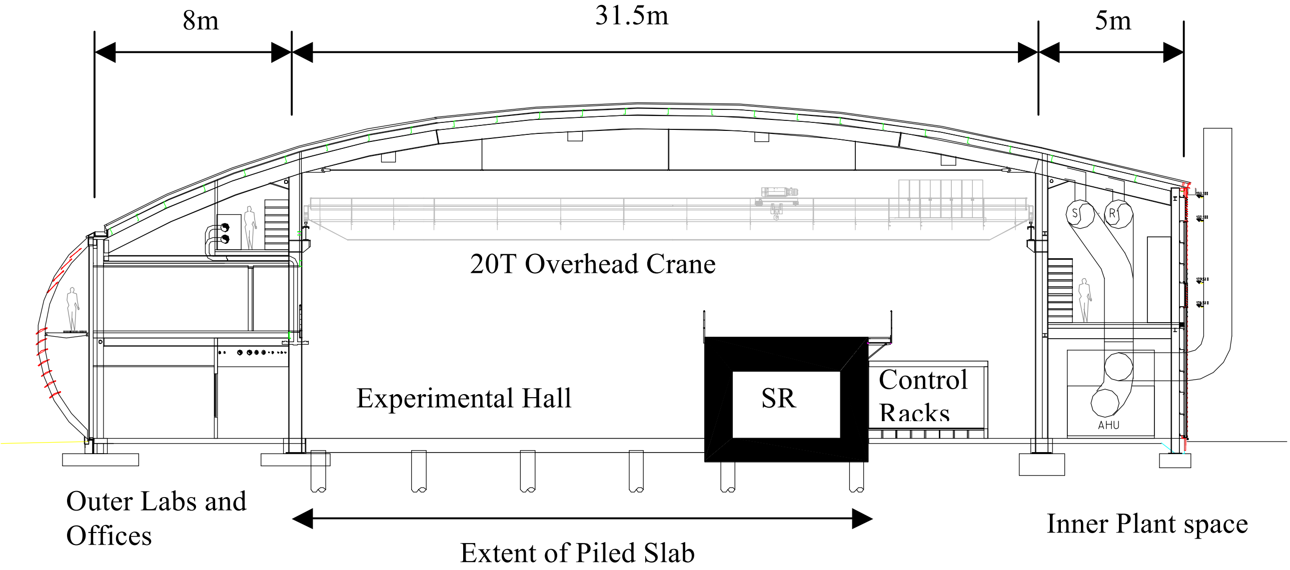

Figure 1: Diamond Building Cross-Section

3. Description of the HLS installation

8 sensors have been positioned along a typical beamline route from Insertion Device to sample along a 60 metre portion of the SR and the EH floor. Figure 2 is a system layout and Figure 3 is a plan drawing of the installation showing the route from inside the SR and out between 2 existing beamlines. The small circles in the plan drawing mark the position and size of the piles. Sensors 1 and 2 are inside the SR tunnel and sensors 3 to 8 are mounted on the EH floor. Sensors 1 to 7 are mounted on the piled slab with sensor 8 mounted just across the construction joint on the surface cast slab at the 3m wide ground floor walk way where there is heavy fork lift truck and foot traffic. Wherever possible the sensors have been mounted 10m apart to allow easy comparison of the difference in adjacent sensor levels with the specification. The HLS sensors are connected together by 2 tubes, one carrying a water channel and the other an air channel. As the sensors share a liquid surface, as one sensor changes height due to changes in local floor level then a height change is detected within the sensor's capacitive measurement system. All sensors with their electronics are calibrated and the output from each sensor is recorded and processed within the Diamond EPICS control system.

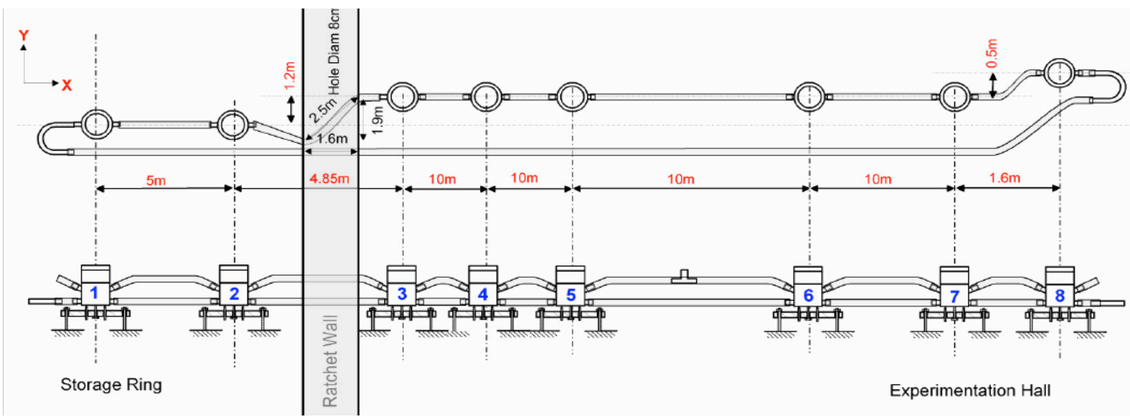

Figure 2: HLS System Layout

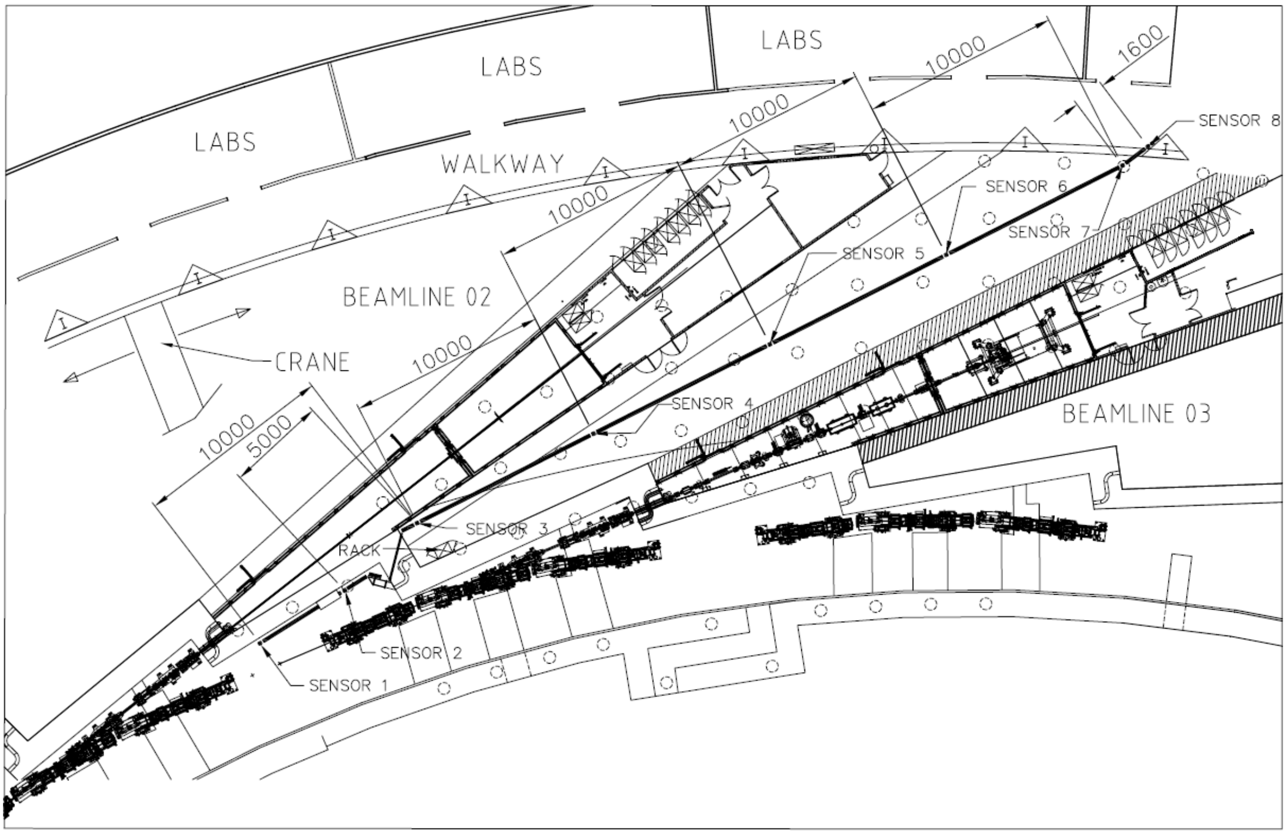

Figure 3: Diamond HLS Installation between 2 Existing Beamlines

4. First Results from the Diamond HLS system

A number of tests have been carried out which are recorded in Table 2. Tests 1-8 involve the overhead crane being moved over the HLS system, stopping at various positions as described. The self weight of the crane is 29T and this load bears down through the steel structure onto pad foundations. Other tests involved driving a 3.7T Fork Lift truck along the length of the HLS installation, stopping at various locations as described. Further load tests were carried out by placing a 1T lifting beam and 0.5T magnet load in various positions. There are options to present the data which include 1. Raw level data from each sensor, 2. Mean Plan presentation which gives heights with respect to the least square fit line through every point and 3. Mean Level which gives heights relative to an average line through all the sensors.

The most sensible results have been calculated using the Mean Level approach which eliminates effects due to temperature drift or changes in sensor height causing a change in water level in the whole system.

The Fogale HLS5 sensors are stated to achieve a resolution of +/-0.2 micron with a measurement uncertainty of +/-1.2 micron but the expectation is to achieve better than this in a laboratory type environment.

Test 19 indicates that a local 3.7T load on the walkway slab causes a significant 46 micron depression but this is not communicated to the EH slab. This means that heavy fork lift truck and foot traffic using the ground floor walkway can continue without affecting beamline operation.

Tests 2 and 8 indicate that half the weight of the overhead crane, approximately 15T, bearing down to local pad foundations in the position of the building columns is compressing the ground locally by 20 microns and this compression is transferring to the piles local to the column and so the hall floor is also depressed but to a lesser extent of 9 microns at the edge. This result was not expected as the piled foundation was to protect the hall floor from such effects. However, it can be seen that at Sensor 5 there is little or no deflection and this is equivalent to the sample position for the majority of Diamond beamlines.

Test 9 and 10 show the effect of driving the crane to Sensor 6, picking up a 1T weight 2m away from the sensor and then placing the weight back on the ground. The difference in sensor 6 is 1 micron due to the change in weight of 1T, hence 0.5 micron would be expected for 500kg or 5kN which is within specification. A similar analysis can be made with results 11 and 12 and the measurements of Sensor 5. Further tests 14-16 were carried out employing a compact 0.5T magnet placed 0.3, 1.0 and 2.0m from Sensor 5 which again show that floor movements under a steady load are within the specification in Table 1.

Table 2: Mean Level Test results from all 8 sensors measured in microns

Number	Test Condition	S1	S2	S3	S4	S5	S6	S7	S8
1	Crane over S5	1.5	1.5	1	0	-1	-2.5	0	1
2	Crane over S8	1	1	1	0	0	-1.5	-9	-21
3	Crane over S5	1	1	0	0	-2	-2.5	0	0
4	Crane over S1	-1.5	-1	-1	0	1.5	1.5	2	1.5
5	Crane 10m Anti Clock Wise	-1.5	-1	-1	0	1.5	1	1.5	1.5
6	Crane 20m Anti Clock Wise	-1	-0.5	-0.5	0	1	1	1.5	1
7	Crane 40m Anti Clock Wise	-1	-0.5	-0.5	0	1	0.5	1	1
8	Crane over S8	0.5	0.5	0.5	0	0.5	-1.5	-8	-20
9	1T lifted from S5/S6 2m away.	1	1	0.5	0	-0.5	-2	-1	0
10	1T 2m from S6	1	1	0.5	0	-0.5	-3	-0.5	0
11	1T 1m from S5	1	1	0	0	-2	0	1	1
12	1T lifted from S5	1	1	0	0	-0.5	0	1	1
13	Crane and 1T removed from area	-1	-1	-1	0	1	1.5	1	0.5
14	0.5T place and remove 2m S5					-0.5			
15	0.5T place and remove 1m S5					-1.0			
16	0.5T place and remove 0.3m S5					-1.5			
17	3.7T Forklift at S7	-1	-1	-1	0	1	1.5	-4	-4
18	3.7T Forklift stops at S5	0	0.5	0	1	-4.5	2.5	2	-0.5
19	3.7T Forklift closer to S8	-1	-1	-1	0	1	2	-1	-46
20	Forklift removed from area.	-1	-1	-1	0	1	2	2	-7

As regards the short and long term settlement criteria in Table 1, Mean Level measurements between adjacent sensors taken over a 24 hour period from 08.00 on the 17/5/08 indicate that;

Greatest range of movement of any sensor = 6.5 microns
Greatest movement in 1 hr of any sensor = 1.5 microns
Greatest difference over 10m in 1 hr = 1 micron

Thus the settlement criteria over 1 hour and over 24 hours have been achieved.
Clearly much more data and time need to elapse before settlement over longer periods can be assessed.

5. Conclusion

A HLS system has been installed at Diamond Light Source along the path of a typical beamline. Initial testing indicates that the specified performance of the slab in terms of deflection under steady loads and short term settlement has been achieved. The system has detected that the piled slab is not independent of crane loads bearing down through the building columns and the edge of the slab is being depressed as the crane passes over. This could have an effect on beamline sample positions close to the edge of the slab but the majority of beamlines have sample positions further from the edge where the floor moves much less. The system has confirmed that heavy fork lift loads and foot traffic can use the peripheral walkway without affecting the piled slab and neighbouring beamlines.